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EVALUATION OF STATE OF CHARGE METERS FOR BA-5800 LITHIUM SULFUR DIOXIDE BATTERIES

Michael J. Wilkin, Anita Esses-Fernandez, Henry Olsen, Terrill Atwater and Jonas Zeman

MARCH 1998

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13. ABSTRACT *(Maximum 200 words)*
Product Manager Global Positioning System (PM GPS) sponsored the test and evaluation of BA-5800/U (a military lithium sulfur dioxide battery) State of Charge (SOC) meters made by two manufacturers, Monica Computers and Quality Power Supplies, Limited. This battery is used to power the AN/PSN-11 Precision Lightweight GPS Receiver (PLGR). Over 70,000 PLGR's have been distributed to the Army by PM GPS with a grand total of 78,800 to be distributed by September 1998. Battery operating costs are the major life cycle cost to the PLGR, and there are no SOC testers for this battery in the Army inventory. Based on field data collected from PLGR users at Fort Drum, NY, an economic analysis concluded that the use of the SOC meter saves 43.9% in the cost of batteries, and the use of 228 SOC meters in active Army units would save $4,270,000 over a 5-year period. Through controlled laboratory testing, it was concluded that the SOC meters from both manufacturers provide a reading accurate to within 10% of actual battery capacity at room temperature and above. At the minimum meter operating temperature of zero degrees Celsius, both meters have greater error and conservatively underestimate the capacity of the battery.

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EXECUTIVE SUMMARY

Product Manager Global Positioning System (PM GPS) sponsored the test and evaluation of BA-5800/U (a military lithium sulfur dioxide battery) State of Charge (SOC) meters made by two manufacturers, Monica Computers and Quality Power Supplies, Limited. Both are Israeli companies. The BA-5800/U battery is used to power the AN/PSN-11 Precision Lightweight GPS Receiver (PLGR). Over 70,000 PLGRs have been distributed to the Army by PM GPS with a grand total of 78,800 to be distributed by September 1998. Battery operating costs are the major life cycle cost to the PLGR, and there are no SOC testers for this battery in the Army inventory.

Based on field data collected from PLGR users at Fort Drum NY, an economic analysis concluded that the use of a SOC meter saves 43.9% in the cost of batteries, and the use of 228 SOC meters in active Army units would save $4,270,000 over a 5-year period.

Through controlled laboratory testing, it was concluded that the SOC meters from both manufacturers provide a reading accurate to within 10% of actual battery capacity at room temperature and above. At the minimum meter operating temperature of zero degrees Celsius, both meters have greater error and conservatively underestimate the capacity of the battery.

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INTRODUCTION

Product Manager Global Positioning System (PM GPS) has fielded to the Army over 70,000 AN/PSN-11 receivers with a grand total of 78,800 to be distributed by September 1998. Although many are used in vehicles and can use vehicle power, at least half are powered by an internal battery. BA-5800 main power batteries are the major life cycle cost to this receiver, commonly called a "PLGR" for Precision Lightweight GPS Receiver. In order to minimize this cost, the PM has taken several actions.

First, the PLGR is designed to be able to utilize a rechargeable battery and to keep this battery charged while the PLGR is used on an external power source. Second, the PLGR is designed to display the estimated remaining operating time for the battery. This feature functions correctly however only when the operator resets the counter when he inserts a new battery. Also, the PLGR gives a low battery warning shortly before the battery is exhausted. If the batteries are used until this warning is received, the operator will minimize battery costs. Third, the last approximately 47,500 receivers produced have had hardware changes to increase the continuous operating time on a BA-5800 battery from 10 hours to greater than 20 hours. Fourth, the PM fielded each PLGR with a battery tray which enables an operator to substitute 8 AA size alkaline batteries for the military BA-5800 battery normally used to power the PLGR. The AA batteries provide a shorter operating time, and are not practical for cold temperature operation, but can lower operating costs during peacetime operations in temperate weather. Finally, the PM purchased a total of 12 prototype BA-5800 State of Charge (SOC) meters from two companies, RBB & Associates Limited (supplier has changed since then to Monica Computers) and Quality Power Supplies Limited (QPS), for evaluation of performance and cost effectiveness. There are no meters in the Army inventory capable of testing this battery and it was suspected that batteries with remaining life were being discarded before PLGR operators began a new mission. It was believed, but not proven, that if SOC meters were introduced to the Army, additional savings would be possible.

The Army Project Manager, Test Measurement and Diagnostic Equipment (PM TMDE), was contacted and supported the PM GPS investigation of the performance and economics of a SOC meter for BA-5800 batteries. The Army already had a larger AC powered bench top SOC meter for other lithium sulfur dioxide batteries, the LS-94 from QPS Limited in Israel. It was purchased by US Army Communications-Electronics Command (CECOM) for PM SINCGARS to test BA-5590 batteries. It could be modified to test BA-5800 batteries, but it was decided not to do so because of the size/weight of the meter and the high cost of the modification.

In order to best determine the capabilities and cost effectiveness of BA-5800 SOC meters, PM GPS Readiness Management Division teamed with other organizations to provide specialized support in their areas of expertise. Mr. Wilkin, who works full time in the PM GPS office, served as Project Leader and coordinated/approved the efforts of the other organizations. The body of this report is divided into several sections with each section representing the input of a different organization. The Executive Summary and Introduction were written by Mr. Wilkin who also served as editor of the complete document.

Section 1.0, the economic analysis, was written by Mrs. Esses-Fernandez and Mr. Olsen of the CECOM Planning, Analysis and Integration Directorate, System Analysis Division. They concluded that use of the SOC meter results in savings of 43.9% in operating costs and could save $4,270,000 over 5 years if 228 meters were used by active Army units. This was based on field data collected from active PLGR users in the 10th Mountain Division at Fort Drum, NY.

Dr. Atwater of the CECOM Command, Control & Systems Integration Directorate, Power System Division wrote section 2.0, the technical evaluation of the SOC meters. He was assisted by Diane Bennington and Dan Berka who performed the laboratory testing on the meters in the CECOM lithium battery test facility. This testing extended for much longer than originally planned as the manufacturers were allowed to make changes to the meter software to correct deficiencies discovered during the testing. Each time this occurred, previous tests had to be repeated. By test completion, the SOC meter from both manufacturers provided satisfactory performance. At room temperature and above the meters were generally accurate to within 10% of actual battery capacity. At the minimum meter operating temperature of zero degrees Celsius, they conservatively underestimated the battery capacity with a generally greater error.

Section 3.0, the human factors evaluation, was written by Mr. Zeman of the US Army Research Laboratory, Human Research & Engineering Directorate, CECOM Field Element. Both meters had similar recommendations for improvements except that the QPS meter cable securely fastened to the meter so it could not accidentally disconnect during a test. Some operators wanted the meters to complete the test more quickly. Also, both meters give a maximum capacity reading for a battery of >70%. Some operators wanted a more precise maximum reading. In both cases the testing technology of lithium batteries currently makes these improvements impossible. Some operators want the meters to be pocket sized. The size of the meter is limited by the heat that must be dissipated during the test process. The current requirement is that the meter be used for continuous testing of BA-5800 batteries and, at the request of the Fort Drum field users, can also be used to test BA-5590 lithium batteries. If the requirement to test BA-5590 batteries was eliminated and the number of BA-5800 batteries tested each hour was limited, it would be technically possible to build a smaller meter. The testing of fewer types of batteries and smaller quantities of batteries per hour, however, would reduce the cost effectiveness of the meter.

Fielding of the replacement for the PLGR to active Army units is scheduled to begin in the year 2001. This will require at least 3 years to complete, pending sufficient funding. The displaced PLGRs will go to the Army Reserve and National Guard. In order to maximize savings to the Army, introduction of the SOC meter should begin as soon as possible as the replacement for the PLGR will probably not use the BA-5800 battery.

The meter called in this report the RBB & Associates meter, or the Bashe Meter, is more correctly named the Lithium Sulfur Dioxide Battery Tester, P/N DM-301. It is now available from Monica Computers, 18 Propess St., Jerusalem 97735, Israel. Point of Contact is Mr. Morris Baruch, telephone 011-972-2586-1801; facsimile number is 011-972-2586-3959. Their US representative is Mr. Bashe at telephone number (717) 698-0498, email: rbbashe@compuserve.com. Their meter is shaped like a commercial multimeter and stands upright at an angle when using a wire stand built into the back of it. It is 3.7 x 6.9 x 1.4 inches in size, weighs 2 pounds without battery cable and is powered by 4 AA size 1.5 volt batteries. See Figure 1 for a photograph of this meter.

The meter called in this report the QPS meter is the HHSCM Battery Tester, P/N 6050-FP00-10. It is available from Quality Power Supplies (QPS) Limited, P.O. Box 3201, Natanya 42132, Israel. Point of Contact is Mr. Israel Reshef, telephone number 011-972-9-658555; facsimile number is 011-972-9-658444. His email is qps@mail.inter.net.il or reshefil@main.aquanet.co.il. QPS does not have a US representative at this time. Their meter is box shaped. To use, the operator flips open the hinged lid of the box to expose the cable connector, control buttons and display. It is 8.25 x 6.25 x 3.25 inches in size, weighs less than 4 pounds and is powered by 2 commercially available 2/3 A size $LiMnO_2$ batteries. See Figure 2 for a photograph of this meter.

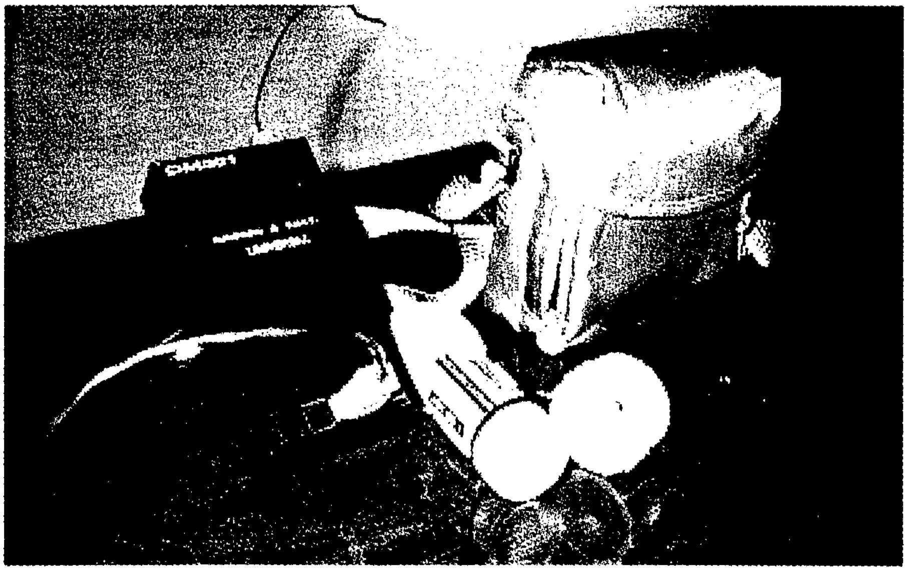

Figure 1
RBB Meter with Carrying Case.

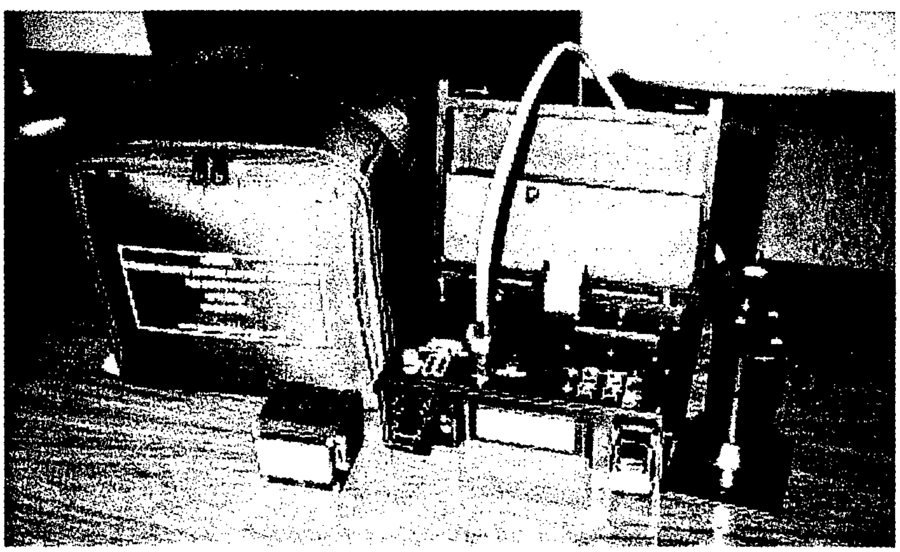

Figure 2
QPS Meter with Carrying Case.

1.0 ECONOMIC ANALYSIS OF A BATTERY STATE OF CHARGE METER FOR THE PRECISION LIGHTWEIGHT GLOBAL POSITIONING SYSTEM RECEIVER

1.1 SUMMARY

The objective of the analysis is to assess the utility and cost effectiveness of a portable battery State of Charge (SOC) meter utilized with the hand held Precision Lightweight Global Positioning System Receiver (PLGR) and the associated BA-5800 battery.

The hand held PLGR utilizes the BA-5800 battery as a power source. Battery costs are a significant operational cost for the hand held PLGR. The remaining capacity or SOC of a used BA-5800 battery cannot be determined by standard battery testers. If battery life is uncertain, the user is likely to install a fresh battery before a new mission, resulting in increased battery costs.

A SOC meter is an effective solution for determining SOC of used batteries and preventing replacement of batteries that have usable SOC remaining. The PM GPS realized the possible usefulness and savings associated with using a SOC meter to test hand held PLGR batteries and thought it worthwhile to determine the value of a SOC meter to units using the hand held PLGR. The PM GPS purchased two types of commercial, portable SOC meters capable of measuring BA-5800 SOC for laboratory evaluation at Fort Monmouth, NJ and field evaluation by an active Army unit at Fort Drum, NY. They requested for CECOM Program Analysis and Evaluation Directorate (PA&E), Systems Analysis (SA) Division, to assess the field data and comment to determine the utility and cost effectiveness of the SOC meter.

The results of the evaluations and analysis indicate that the meters effectively perform their function of determining battery SOC. The results also indicate that a savings of $4.27 Million over a 5-year period (Current Dollars) could be obtained with the use of 228 SOC meters in active Army units using the hand held PLGR. Field data indicate that a savings of 43.9 % in the cost of batteries could be obtained from use of the SOC meter.

It is recommended that units using hand held PLGRs be made aware of the savings expected from the use of a SOC meter and afforded an opportunity to purchase a meter if it is in their interest to do so.

1.2 OBJECTIVE

The objective of this analysis is to assess the utility and cost effectiveness of a portable battery State of Charge (SOC) meter utilized with the hand held Precision Lightweight Global Positioning System Receiver (PLGR) and the associated BA-5800 battery.

1.3 BACKGROUND

The PLGR uses the BA-5800 lithium sulfur dioxide battery as the power source in hand held applications. This battery provides 12 hours of continuous use at room temperature in the older PLGR version (tan case) and 20 hours of continuous use in the newer versions (green case). Battery costs can be a significant operational cost to Army units using the hand held version of the PLGR. The remaining capacity or SOC of a used BA-5800 battery cannot be determined by standard battery testers. The PLGR estimates the remaining life in a BA-5800 only if the operator resets the battery life feature in the PLGR each time the battery is replaced. This PLGR feature also works with a used battery, but only if the operating time of the used battery is known and entered before inserting the battery into the PLGR. If the life of a battery is uncertain, a user is likely to install a fresh battery before a mission. This increases battery operating costs. Another source of increased battery costs is passivated batteries. These are new batteries which have been in extended storage and are good, but may appear dead upon initial use due to a passivation effect (corrosion reaction internal to lithium battery cells).

A SOC meter is an effective solution to the above problems because it enables a quick and easy determination of battery SOC. A bench type SOC meter is being used successfully by field units for the BA-5590 and other types of lithium batteries. The current bench type meter does not have a capability to measure SOC for the BA-5800 battery, although the capability could probably be added. The portable SOC meter is more desirable than the bench type meter with a 120 volt AC power requirement because it provides flexibility as to where and when the meter may be used. A SOC meter should reduce PLGR operating costs because field units are more likely to completely utilize a battery's charge when they can easily verify SOC. If a field unit has a Standard Operating Procedure (SOP) to use batteries as long as possible, a SOC meter makes it easy to verify if the SOP is being followed. If the SOC is unknown, batteries are more likely to be turned in for fresh ones at the start of a mission or exercise. The PM GPS realized the possible usefulness of a portable SOC meter used in conjunction with the hand held PLGR. The PM GPS thought it worthwhile to determine the value to field units of a SOC meter for PLGR. The PM GPS purchased two types of commercial hand held, portable SOC meters capable of measuring BA-5800 SOC for laboratory and field evaluation.

The PM GPS arranged for both of the SOC meters they purchased to be evaluated in the laboratory by CECOM Advanced Systems Directorate (ASD) Power Sources Division. This evaluation would determine whether the meters met basic specifications and the operating characteristics under various temperature conditions, and whether meters were safe to operate.

The QPS SOC meter was not field tested for this analysis, as it was not available for distribution when the field evaluation began in November 1995. The RBB SOC meter was provided to the 10th Mountain Division Support Company at Fort Drum, New York for the field evaluation. SOC battery data and comments on the meter were gathered from November 95 to July 96 to enable assessment of the utility and cost effectiveness of the meter. The CECOM Program Analysis and Evaluation Directorate (PA&E), Systems Analysis (SA) Division, assessed field data and comments to determine the utility and cost effectiveness of the SOC meter. The QPS meter was later used by Fort Drum for comments on usage, but not for economic data gathering purposes. Since the technical performance was determined to be similar, if the costs of the RBB and QPS meters are similar the results from this economic analysis would apply to both.

The CECOM Human Factors (HF) Office also assessed the SOC meter. They prepared a Human Factors questionnaire and solicited comments from field unit evaluators.

1.4 SYSTEM DESCRIPTIONS

Two SOC battery testers, the RBB & Associates DM 301 Meter and Quality Power Supply (QPS) Hand Held Meter, were considered in this analysis. Both were evaluated and tested by the CECOM ASD Power Sources Division. The RBB Battest DM301 meter was provided to Fort Drum for a field evaluation.

The RBB & Associates Battest DM301 meter provides an immediate test capability for selected types of Ballard, PCI, and SAFT lithium batteries. Additional types of batteries or manufacturers may be added with software modifications. The DM301 can be used to test BA-5800, BA-5847, and BA-5590 type lithium batteries. This meter is portable and measures the battery state of charge to an accuracy of 10%. It reads to the nearest 1% from 0 to 70% SOC and indicates if the SOC is greater than 70% for values from 71 to 100% SOC. The DM301 has a self test feature, as well as the ability to identify defective batteries and then immediately stop the ongoing battery test. It is splash resistant but not waterproof. The DM301 has a lightweight aluminum case and derives its operating power from four AA size alkaline or lithium iron disulphide batteries.

The QPS SOC meter provides an immediate test capability for Ballard, PCI, and SAFT lithium batteries. The QPS can be used to test BA-5800 and BA-5590 lithium batteries. Additional types of batteries or manufacturers may be added with software modifications. This meter is portable and measures the battery state of charge to an accuracy of 15%. The QPS meter has seven levels of SOC readings: 0-10, 20, 30, 40, 50, 60, and 70+ per cent SOC. It is waterproof. The meter is ruggedized and derives its operating power from "2/3 A size" lithium magnesium dioxide batteries.

1.5 ALTERNATIVES

The status quo and a SOC meter alternative were evaluated. The status quo evaluates BA-5800 battery and disposal costs for hand held PLGR operation without a SOC meter. The alternative evaluates battery and disposal costs using a SOC meter.

1.6 ASSUMPTIONS/DATA

PM GPS reviewed and concurred with the following assumptions.

A. It is estimated that 50% of the PLGRs are vehicle installed and 50% are hand held units. The SOC meter will only be used for batteries with the hand held PLGR because batteries are the primary power source of the hand held PLGR and are used only as a backup power source on the vehicle installed PLGRs. Because of recent safety incidents with batteries in PLGRs while in vehicles, use of a BA-5800 in a PLGR on external power is prohibited.

B. It is estimated that 90% of the Army demand for BA-5800 batteries is for use in hand held PLGRs and 10% for use with other equipments. The BA-5800 battery demand for June 95 to June 96 was 239,963. Therefore, battery demand for the hand held PLGR was 239,963 x 90% = 213,267. It is assumed that 50% of batteries used would be checked by the SOC meter. It is assumed that units using the meter would be those units that use a substantial number of BA-5800 batteries in hand held PLGRs. The balance of batteries would be used in units and applications where a SOC meter is not available, or where it was not felt to be economically advantageous.

C. The number of PLGRs fielded to active Army units is approximately 39,500 (June 1996). An additional 6,000 PLGRs will be fielded through FY97 and FY98 to active Army units, and 28,000 to Army Reserve and National Guard units. It is assumed that most of the Reserve and Guard unit PLGRs will see intermittent use, with long periods of storage. For this analysis, it was estimated that current battery use for PLGRs in active units would increase directly in proportion to additional PLGR fieldings to active units, or 6,000 / 39,500 = 15.18 (100) = 15% over FY 97 - FY 98. This will increase BA-5800 battery demand 32,000 per year (increase of 15% over current demand). For cost purposes, battery demand was increased by 7.5% per year for two years and leveled off. For this analysis, it was assumed that Guard and Reserve units would not utilize SOC meters.

D. The ratio of SOC meters to PLGRs from the previous study, <u>BA-5800 Lithium Battery State of Charge (SOC) Meter Cost Evaluation</u>, May 1995, was retained for this effort. The PM GPS expressed a desirable ratio of SOC meters to PLGRs as one meter per 100 hand held PLGRs. This equates to 228 SOC meters to accommodate the hand held PLGRs. Calculation:
(45,500 PLGRs * 50% hand held PLGRS)/100 PLGRs per meter = 228 meters.

F. Current disposal cost for discharged lithium batteries averages 25 cents per pound, per C. Rutkowski, AMC Battery Group. The BA-5800 weighs 1 pound. The BA-5800 is considered nonhazardous when completely discharged.

G. It was assumed the SOC meter fielded to Fort Drum met specifications. The field unit used the standard meter operating procedure to perform the SOC test and accurately recorded the SOC as indicated by the meter. The field unit assumed batteries with a ≥ 38% SOC would be reissued as new for field use.

H. The economic life for the current BA-5800 battery technology is 5 years. There are no plans to change the current lithium disulfide ($LiSO_2$) technology within this timeframe. The economic life of the portable SOC meter is 5 years. There are no present plans to put a built-in SOC meter into the BA-5800 battery. The FY 97 Army Master Data File (AMDF) price for the BA-5800 is $17.97.

I. The DM 301 and QPS SOC meters cost $4,000 each based on a quantity of 6. A recent purchase of 92 SOC meters produced by QPS for the BA-5112 battery had a unit cost of $1,200. After discussion with a representative from PM GPS, it was assumed for this analysis that the cost of a BA-5800 SOC meter (with additional battery type capabilities) would decrease from $4,000 to $1,200 in a quantity buy of 200 - 250 meters.

J. The PM GPS began fielding AA battery trays for use with PLGR in the Fall 1995. One AA tray holds 8 AA batteries and one is fielded for every two PLGRS. An AA tray provides 4 hours of continuous use at room temperature in the older PLGR version (tan case) and 8 hours of continuous use in the newer versions (green case). The Fort Drum unit did not use AA batteries for PLGR power. Since the field usage pattern for AA batteries in the PLGR is unknown at this time, the use and cost of AA alkaline batteries was not evaluated.

K. It was assumed for this analysis that the batteries sent for test would otherwise have been sent to disposal. **Battery savings are counted only for batteries reissued as new.** Based on previous and current field test data, it was assumed that savings of 40% would be obtained in battery costs (see 1.7 METHODOLOGY).

L. The cost for batteries to power the SOC meter is minor and not considered for this analysis.

1.7 METHODOLOGY

An economic analysis was conducted to estimate the savings achieved from the use of a SOC meter. Two previous analyses (Cost and Savings Analysis of State of Charge (SOC) Indicator Devices for Lithium Sulfur Dioxide Batteries, October 1991, and BA-5800 Lithium Battery State of Charge (SOC) Meter Cost Evaluation, May 1995) and a previous field test have indicated that the use of a SOC meter would save 20% to 40% of battery costs. The estimate of 40% was obtained from a field test of BA-5590 batteries turned in for disposal, and used for the October 1991 analysis. The 40% result was for BA-5590 batteries utilized with SINCGARS radios and reflects a one battery one mission mindset. The one battery one mission policy no longer reflects standard operating procedure. Typical procedure now is to recommend battery use until a 30% SOC is reached; or until equipment will not operate.

The estimate of 20% savings in battery usage was formulated in the May 1995 analysis based on factors which included the PLGR carrying a spare battery. It was felt there would be a tendency to use the PLGR battery until the system will not operate, and then replace the battery with the available spare.

Two sets of data concerning SOC of BA-5800 batteries were obtained from the field test at Fort Drum (see details below). Results obtained from data set 1 indicated a 43.9% savings was obtained. Data set 2 indicated no savings, but there are two reasons that explain this change:

a) These batteries were previously reissued, and had SOC depleted prior to second use.
b) The units were now aware that SOC would be accurately checked at battery turn in. Hence there was a greater impetus to follow the SOP of not turning in batteries with > 30% SOC.

Based on data set 1 and the previous BA-5590 field tests, it was assumed for the economic analysis that an overall 40% savings in battery costs would be achieved from use of a SOC meter. Spreadsheets were developed for the economic analysis to determine the expected savings from SOC meter use over a 5 year period based on a 40% savings.

A sensitivity analysis, using a 20% estimate for savings was performed to investigate variations in data and savings. Additionally, computations were made to determine how long it would take the meter to pay for itself at savings rates of 20% and 40%.

1.8 RESULTS

A. Test Results:

Fort Drum established SOC > 38% as a criteria for battery reissue. The unit estimated they have 50 PLGRs under their purview. The unit SOP for SOC testing was: Batteries with a SOC from 38 to 69% would be reissued for training purposes; batteries with a SOC ≥ 70% would be reissued as new; and batteries with SOC ≤ 37% would be turned in for disposal. The data provided by Fort Drum shows how many batteries were tested and how many of those were reissued as new, reissued for training, or sent for disposal. Three groups of battery test data were provided by Fort Drum. The first group tested 173 previously used BA-5800 batteries. Of the 173 used batteries tested, 76 were reissued as new, and 36 were reissued as usable for training, and 61 were turned in for disposal. This resulted in a reissue rate of 43.9% as new and 20.8% for training for the first group of BA-5800 batteries tested. Therefore, data obtained from data set 1 indicated a 43.9% savings was obtained when using the SOC meter. Battery test data are provided in Appendix A.

In the second group of test data, 90 used BA-5800s were tested. This second group consisted mainly of batteries that had been reissued as a result of the first test. Only 5 batteries were reissued from the second group of 90 BA-5800s tested. All were reissued for training purposes only. Hence, 0% were reissued as new. Data set 2 indicated no savings, but there are two reasons that explain this change:

a) These batteries had been previously used, and had SOC depleted prior to second use.

b) The units were now aware that SOC would be accurately checked at battery turn in. Hence there was a greater impetus to follow SOP of not turning in batteries with > 30% SOC.

The third group of test data included only BA-5590 batteries. Only BA-5590s were tested because the testing unit at Fort Drum misunderstood instructions and thought they were <u>not</u> to test any more BA-5800 batteries.

B. Economic Analysis Results:

Based on the assumption of Paragraph 1.6, 228 meters at a cost of $273,600 ($1,200 each) would be distributed to active Army units using hand held PLGRs. The savings shown in Table 1 are projected over a 5 year period from distribution of the 228 SOC meters, assuming a 40% savings from SOC usage:

Table 1
Investment and Savings

SOC METER ALTERNATIVE			COST AND BENEFITS DISPLAY ($K)					
		Constant Dollars		PV Factor	Discounted Dollars	Inf Factor	Current Dollars	
		(Base Year FY96)			(Present Value)		(Inflated)	
Evaluation	Operation Cost		Benefits		Benefits		Benefits	
Period	Status Quo	SOC Alternative	(Differential Costs)		(Differential Costs)		(Differential Costs)	
(1)	(2)	(3)	(4) = (2) - (3)		(5) = (4) x Disc. Fac.		(6) = (4) x Infl. Fac.	
FY 96						0.995		
FY 97	3,851,602	3,081,282	770,320	0.9868	760,152	1.0164	782,954	
FY 98	4,140,472	3,312,377	828,094	0.9608	795,633	1.0392	860,556	
FY 99	4,451,013	3,560,811	890,203	0.9356	832,874	1.0625	945,840	
FY 00	4,451,013	3,560,811	890,203	0.911	810,975	1.0859	966,671	
FY 01	4,451,013	3,560,811	890,203	0.887	789,610	1.1098	987,947	
FY 02				0.8637		1.1342		
Residual Value								
Total	21,345,114	17,076,091	4,269,023		3,989,243	(7)	4,543,968	(10)
		Investment Cost			Investment Cost		Investment Cost	
		273,600			269,988	(8)	278,087	(11)
		Project Total Cost			Net Present Value		Net Benefits	
		17,349,691			3,719,255	(9)	4,265,881	
			BIR=	14.78	SIR=	14.78		

The baseline results indicate a savings of $4.27 Million (Current Dollars) over a 5 year period with benefit and savings to investment ratios of 14.78. Hence, the use of a SOC meter is cost effective. Spreadsheets showing calculations for the economic analysis and cost data with sources are provided in Appendix B.

C. Additional Factors:

1) Utility and nonquantifiable benefits for hand held SOC:

a) Troops at Fort Drum commented that they felt the hand held meter was easier to use than the bench type SOC.

b) The hand held meter is small, portable and lightweight.

c) The hand held meter is quicker in operation than the bench type meter.

d) The hand held meter tests both the BA-5800 and the BA-5590 battery. The bench meter presently tests only the BA-5590, not the BA-5800. Other types of batteries could be added to bench or hand held meters. Troops wanted the capability to test BA-5590 batteries.

e) Either meter can easily verify if field units are using batteries to the recommended or SOP levels of SOC. If troops know that battery SOC will be checked, it is more likely the batteries will be utilized to a lower level of SOC.

2) Troops commented they would like the meter to provide an audible beep at completion of test.

3) Per the AMC battery group, the BA-5800 battery is not likely to acquire a built-in SOC indicator in the near future (5 years).

1.9 SENSITIVITY ANALYSIS

Based on the BA-5800 Lithium Battery State of Charge (SOC) Meter Cost Evaluation, May 1995, it was assumed a 20% savings would be achieved from the use of a SOC meter with PLGR. Based on the assumption of Paragraph 1.6, 228 meters would be distributed to active Army units using hand held PLGRs. The savings shown in Table 2 are projected over a 5 year period from distribution of the 228 SOC meters and a 20% savings rate.

The results indicate a savings of $1.99 Million over a 5 year period (Current Dollars) with benefit and savings to investment ratios of 7.39. Hence, the use of a SOC meter is still cost effective (even at the reduced savings rate). Spreadsheets for the sensitivity analysis are provided in Appendix C.

1.10 BREAK-EVEN ANALYSIS

At a savings rate of 40%, each battery used by a unit with a SOC meter would result in dollar savings of $7.22 per battery ([Unit cost of $17.81 + .25 disposal cost] x 0.40 savings rate). The meter cost is assumed to be $1,200 per meter. In one year, a unit could save enough in battery costs to pay the purchase cost of a meter if it tested 167 batteries per year. At a savings rate of 20%, a unit would pay for the cost of a meter if it tested 333 batteries per year.

1.11 CONCLUSIONS

SOC meter usage will be cost effective. It will foster the use of batteries to the recommended SOC levels before turn in for disposal, and allow and ensure reuse of batteries with usable SOC. With a savings rate of 40%, a unit that tests 167 BA-5800 batteries per year would pay for the purchase cost of a meter in one year. At a 20% savings rate, a unit that tests 333 batteries per year would pay for the purchase of a SOC meter in one year. Future savings would directly reduce battery costs to field units.

1.12 RECOMMENDATIONS

Recommend field units be made aware that a SOC meter can save substantial battery costs, and provide other non cost advantages that make it desirable to use a SOC meter.

The PM GPS should publish the results of the test so that field units can become aware of the SOC meter's capabilities, human factors assessment, and economic advantages to meter use. Meter purchase would be optional to individual units.

Table 2
Sensitivity Analysis Investment and Savings

SENSITIVITY RUN			COST AND BENEFITS DISPLAY ($K)					
		Constant Dollars		PV Factor	**Discounted Dollars**	Inf Factor	**Current Dollars**	
		(Base Year FY96)			(Present Value)		(Inflated)	
Evaluation	Operation Cost		Benefits		Benefits		Benefits	
Period	Status Quo	Alternative A	(Differential Costs)		(Differential Costs)		(Differential Costs)	
(1)	(2)	(3)	(4) = (2) - (3)		(5) = (4) x Disc. Fac.		(6) = (4) x Infl. Fac.	
FY 96	.	0	0	0	0	0.995	0	
FY 97	3,851,602	3,466,442	385,160	0.9868	380,076	1.0164	391,477	
FY 98	4,140,472	3,726,425	414,047	0.9608	397,817	1.0392	430,278	
FY 99	4,451,013	4,005,912	445,101	0.9356	416,437	1.0625	472,920	
FY 00	4,451,013	4,005,912	445,101	0.911	405,487	1.0859	483,336	
FY 01	4,451,013	4,005,912	445,101	0.887	394,805	1.1098	493,973	
FY 02				0.8637	0	1.1342	0	
Residual Value								
Total	21,345,114	19,210,603	2,134,511		1,994,622	(7)	2,271,984	(10)
		Investment Cost			Investment Cost		Investment Cost	
		273,600			269,852	(8)	278,087	(11)
		Project Total Cost			Net Present Value		Net Benefits	
		19,484,203			1,724,770	(9)	1,993,897	
			BIR=	7.39	SIR=	7.39		

2.0 TECHNICAL EVALUATION OF BATTERY STATE OF CHARGE METERS FOR BA-5800/U LITHIUM SULFUR DIOXIDE BATTERIES

2.1 INTRODUCTION

Prediction of the capacity remaining in used batteries is important information to the user. Each year millions of dollars are spent on batteries for use in portable electronics equipment. In order to maintain readiness, users currently replace batteries on a conservative schedule. This practice results in the waste of millions of dollars in battery energy every year. This practice also results in the discarding of approximately 40 percent of available battery capacity. For many battery systems there is no convenient method of determining the available capacity remaining in partially used batteries, hence, users do not take full advantage of all the available battery energy. Knowledge of capacity remaining in used batteries results in their better utilization.

2.2 BACKGROUND

It is a well documented and accepted that the available capacity in a battery is a function of the conditions to which the battery has been subjected. Capacity remaining is a complex function of current drain, temperature and time. External devices are available for most battery systems. However, in many cases these devices are not portable and are imprecise. Therefore a continuous internal means of determining remaining capacity is desirable. These internal methods require extensive calibration and in many cases are difficult to implement. The pursuit of a universal state-of-charge indicator has been elusive due to the variation in behavior of battery systems.

Reliable methods of predicting remaining capacity have been actively sought. This effort has produced different methods of determining lithium sulfur dioxide battery state of charge and the application of these methods to different battery systems. In order to verify and establish the limitations of these state-of-charge devices when evaluating batteries subjected to military environments and applications, a test procedure has been established. Table 3 shows the basic criteria for this analysis.

Table 3
State of Charge Indicator Verification and Limitation Test Matrix

Test → Conditions Battery Capacity Test Points ↓	Discharge Rate: Application Specific Temperature: @ +20C Meter Evaluation @ +20C	Discharge Rate: Application Specific Temperature: @ -20C Meter Evaluation @ 0C	Discharge Rate: Application Specific Temperature: @ -20C Meter Evaluation @ +20C	Discharge Rate: Application Specific Temperature: @ +50C Meter Evaluation @ +50C
100%, 75%, 66%, 50%, 33%, 25% and 0%	Minimum 2 batteries from each Manufacturer	Minimum 2 batteries from each Manufacturer	Minimum 2 batteries from each Manufacturer	Minimum 2 batteries from each Manufacturer

2.3 TEST PLAN

A. General

1. BA-5800/U Batteries procured under US Army contract and manufactured by Power Conversion Inc. (PCI) and Ballard Battery Co. (BAL) will be utilized for testing.

2. All batteries will be discharged at 0.5 amps to a 2.0 volt cutoff.

3. All batteries will be discharged using equipment calibrated for Independent Government Testing (IGT). Independent Government Testing was established to ensure the quality and safety of batteries procured by the US Army. The equipment includes computer controlled automatic battery cycler. Equipment control allows for precise voltage, current and time of the battery discharge.

4. Four batteries from each manufacturer will be discharged at .5 amps to 2 volts at 20 C for the purpose of establishing background discharge capacity and time. The average time for the four background discharge capacities will be used to determine the required discharge times for the test levels required. The discharge times will be 0.25 times the background time.

B. Test plan for Quality Power Supply Inc. (QPS) State of Charge (SOC) Meter (see Table 4 for Test Matrix)

1. Sequencing for test no. 1

a. Eight batteries (5 PCI and 3 Ballard) will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

b. The eight batteries will be discharged at 0.5 amps at +20 C for 0.25 times the established background. The date and time of test will be recorded.

c. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

d. The eight batteries will be discharged at 0.5 amps at +20 C for 0.25 times the established background. The date and time of test will be recorded.

e. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

f. The eight batteries will be discharged at 0.5 amps at +20 C for 0.25 times the established background. The date and time of test will be recorded.

g. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

h. The batteries will then be discharged to end of life. The date and time of test will be recorded.

Table 4
Modified Test Matrix For QPS BA-5800/U State of Charge Meter Evaluation

Test → Conditions Battery Capacity Test Points ↓	Discharge @ 0.5 Amps @ +20C Meter Eval. @ +20C	Discharge @ 0.5 Amps @ -20C Meter Eval. @ 0C	Discharge @ 0.5 Amps @ -20C Meter Eval. @ +20C	Discharge @ 0.5 Amps @ +50C Meter Eval. @ +50C
PCI				
100%,75%, 50%, 25% and 0%	5 Batteries	4 Batteries	4 Batteries	5 Batteries
Ballard				
100%,75%, 50%, 25% and 0%	3 Batteries	3 Batteries	2 Batteries	3 Batteries

i. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

2. <u>Sequencing for test no. 2</u>

a. Seven batteries (4 PCI and 3 Ballard) will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

b. The batteries will be evaluated on the SOC meter at 0 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

c. Seven batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

d. The batteries will be evaluated on the SOC meter at 0 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

e. Seven batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

f. The batteries will be evaluated on the SOC meter at 0 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

g. The batteries will then be discharged to end of life. The date and time of test will be recorded.

h. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

3. <u>Sequencing for test no. 3</u>

a. Six batteries (4 PCI and 2 Ballard) will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

b. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

c. Six batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

d. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

e. Six batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

f. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

g. Six batteries will then be discharged to end of life. The date and time of test will be recorded.

h. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

4. <u>Sequencing for test no. 4</u>

a. Eight batteries (5 PCI and 3 Ballard) will be discharged at 0.5 amps at 50 C for 0.25 times the established background. The date and time of test will be recorded.

b. The batteries will be evaluated on the SOC meter at 50 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

c. Eight batteries will be discharged at 0.5 amps at 50 C for 0.25 times the established background. The date and time of test will be recorded.

d. The batteries will be evaluated on the SOC meter at 50 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

e. Eight batteries will be discharged at 0.5 amps at 50 C for 0.25 times the established background. The date and time of test will be recorded.

f. The batteries will be evaluated on the SOC meter at 50 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

g. The batteries will then be discharged to end of life. The date and time of test will be recorded.

h. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

5. The total discharge time (summation of each individual 25% discharge step, including discharge to end of life) will be used for determination of battery actual state of charge. State of charge will be calculated by dividing the cumulative discharge time after state of charge testing by the total discharge time.

C. Test plan for RBB and Associates, Ltd. (RBB) State of Charge Meter (see Table 5 for Test Matrix)

1. Sequencing for test no. 1

a. Five batteries (3 PCI and 2 Ballard) will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

b. The five batteries will be discharged at 0.5 amps at +20 C for 0.25 times the established background. The date and time of test will be recorded.

c. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

d. The five batteries will be discharged at 0.5 amps at +20 C for 0.25 times the established background. The date and time of test will be recorded.

e. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

f. The five batteries will be discharged at 0.5 amps at +20 C for 0.25 times the established background. The date and time of test will be recorded.

g. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

Table 5
Modified Test Matrix for RBB BA-5800/U State of Charge Meter Evaluation

Test → Conditions Battery Capacity Test Points ↓	Discharge @ 0.5 Amps @ +20C Meter Eval. @ +20C	Discharge @ 0.5 Amps @ -20C Meter Eval. @ 0C	Discharge @ 0.5 Amps @ -20C Meter Eval. @ +20C	Discharge @ 0.5 Amps @ +50C Meter Eval. @ +50C
PCI				
100%,75%, 50%, 25% and 0%	3 Batteries	3 Batteries	2 Batteries	3 Batteries
Ballard				
100%,75%, 50%, 25% and 0%	2 Batteries	3 Batteries	2 Batteries	3 Batteries

h. The batteries will then be discharged to end of life. The date and time of test will be recorded.

i. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

2. Sequencing for test no. 2

a. Six batteries (3 PCI and 3 Ballard) will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

b. The batteries will be evaluated on the SOC meter at 0 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

c. Six batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

d. The batteries will be evaluated on the SOC meter at 0 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

e. Six batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

f. The batteries will be evaluated on the SOC meter at 0 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

g. The batteries will then be discharged to end of life. The date and time of test will be recorded.

h. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

3. Sequencing for test no. 3

a. Four batteries (2 PCI and 2 Ballard) will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

b. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

c. Four batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

d. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

e. Four batteries will be discharged at 0.5 amps at -20 C for 0.25 times the established background. The date and time of test will be recorded.

f. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

g. Four batteries will then be discharged to end of life. The date and time of test will be recorded.

h. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

4. Sequencing for test no. 4

a. Six batteries (3 PCI and 3 Ballard) will be discharged at 0.5 amps at 50 C for 0.25 times the established background. The date and time of test will be recorded.

b. The batteries will be evaluated on the SOC meter at 50 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

c. Six batteries will be discharged at 0.5 amps at 50 C for 0.25 times the established background. The date and time of test will be recorded.

d. The batteries will be evaluated on the SOC meter at 50 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

e. Six batteries will be discharged at 0.5 amps at 50 C for 0.25 times the established background. The date and time of test will be recorded.

f. The batteries will be evaluated on the SOC meter at 50 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

g. The batteries will then be discharged to end of life. The date and time of test will be recorded.

h. The batteries will be evaluated on the SOC meter at +20 C. If two meters are available for evaluation the group will be divided into two groups. The date and time of the test as well as the meter serial number and reading will be recorded.

5. The total discharge time (summation of each individual 25% discharge step, including discharge to end of life) will be used for determination of battery actual state of charge. State of charge will be calculated by dividing the cumulative discharge time after state of charge testing by the total discharge time.

A sample data sheet is shown on the next page.

BA-5800 Lithium Battery State of Charge Meter Evaluation

Battery Identification
Manufacturer: _____ Serial No. _____ Contract No. _____ Date Code. _____

Test Type: Background _____ 25% _____ 33% _____
Discharge Temperature +20 C _____ -20 C _____ +50 C _____
SOC Test Temperature +20 C _____ 0 C _____ +50 C _____

Discharge #1 (25% only):

Date: __________ Time: __________
Current: __________ Temperature: __________ Discharge Time: __________

SOC TEST #1

Date: __________ Time: __________ Temperature: ___________
Meter No. _____________ Meter Reading: _______________

Discharge #2:

Date: __________ Time: __________
Current: __________ Temperature: __________ Discharge Time: __________

SOC TEST #2:

Date: __________ Time: __________ Temperature: ___________
Meter No. _____________ Meter Reading: _______________

Discharge #3:

Date: __________ Time: __________
Current: __________ Temperature: __________ Discharge Time: __________

SOC TEST #3

Date: __________ Time: __________ Temperature: ___________
Meter No. _____________ Meter Reading: _______________

Final Discharge:

Date: __________ Time: __________
Current: __________ Temperature: __________
Discharge Time to Two Volts: __________

2.4 RESULTS

Tables 6 through 13 show the results of the meter evaluation. Table 6 shows the results of the evaluation of the QPS SOC meter with the batteries discharged and tested at 20 C. Tables 7 and 8 show the data for the QPS SOC meter with the batteries discharged at -20 C and tested at either 0 C or -20 C. Table 9 shows the data for the QPS SOC meter for batteries discharged and tested at 50 C. Table 10 shows the results of the evaluation of the RBB SOC meter with the batteries discharged and tested at 20 C. Tables 11 and 12 show the data for the RBB SOC meter with the batteries discharged at -20 C and tested at either 0 C or -20 C. Table 13 shows the data for the RBB SOC meter for batteries discharged and tested at 50 C.

Both RBB and QPS upgraded the software for the meters to reflect battery response information acquired during initial phases of this evaluation. The results presented are for the final design for both the QPS and RBB meters. The ability of the manufacturers to change the software to include new data and information regarding the batteries to be tested indicates a flexible meter design. This flexible design would allow for additional calibration curves for additional battery designs to be tested.

A. Evaluation of state of charge meter manufactured by QPS

1. When evaluating discharged batteries at room temperature the QPS meter generally performed within a 10% margin of error. This includes batteries discharged at -20 C then tested at 20 C.

Exceptions include:

a. Low indication for fresh PCI batteries (100%). These batteries indicated either 50% or 40% or a CCV fail reading. The CCV reading indicated that the battery failed to supply the required voltage at the test current (Closed Circuit Voltage (CCV) failure). This error can be attributed to an anode passive film due to the age of the batteries, 4.5 years old.

b. Low indication for batteries discharged to 70% at -20 C. These batteries indicated 50% SOC for two batteries and 60% for two batteries.

c. Low indication for a battery that delivered low capacity. During the 20 C discharge a sample failed to deliver expected capacity (delivered 85% expected capacity). The meter indicated 50% SOC when the battery was tested at 71% actual SOC.

2. When evaluating batteries that were discharged at -20 C and then tested at 0 C the QPS meters generally indicated states of charge much lower than the actual state of charge of the battery. This error was greater at higher states of charge, with reading up to 30% low and at best 15% low. The error in the SOC reading decreased with decreasing actual battery state of charge. Errors in the reading when the battery was at 40-50% SOC were on the order of 15%.

3. When evaluating batteries at high temperatures the QPS meter predicted the state of charge within a 10% error with a few isolated exceptions.

B. Evaluation of state of charge meter manufactured by RBB

1. When evaluating discharged batteries at room temperature the RBB meter generally performed within a 10% margin of error. This includes batteries discharged at -20 C then tested at 20 C.

The exceptions include:

a. Low indications for fresh PCI batteries (100%). These batteries indicated either 28% or 33% SOC. This error can be attributed to an anode passive film due to the age of the batteries, 4.5 years old.

2. When evaluating batteries that were discharged at -20 C and then tested at 0 C the RBB meters generally indicated states of charge much lower than the actual state of charge of the battery. This error was greater at higher states of charge, with reading up to 30% low and at best 15% low. As the actual battery state of charge decreased the error in the reading did also. Errors in the reading when the battery was at 40-50% SOC were on the order of 15%.

3. When evaluating batteries at high temperatures the RBB meter predicted the state of charge within a 10% error with a few isolated exceptions. The major exceptions were high indications for 50% SOC Ballard batteries. These batteries indicated >70% when tested at 50 C.

2.5 CONCLUSIONS

The results show that both meters performed similarly. This is expected since the algorithm and test procedure for both meters are based on the same basic evaluation criteria. These criteria are based on the response of the battery under test to a pulse discharge and relaxation. The method of pulse and recovery evaluation for batteries gives an indication of the quantity of active material in the battery. This can pose difficulties in calibration especially for batteries discharged in inefficient environments. Low temperature discharge is a good example of a low efficient environment for electrochemical systems. Both meters provided a conservative indication of state of charge for this region of inefficient battery discharge. Except for unused passivated batteries, at 20 C and above both meters generally performed within a 10% margin of error.

Table 6
Results of QPS State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at 20C and Tested at 20C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI Q2020 1	100	100	50 R 50	-50
	75	75	70-100	0
	50	50	50	0
	25	25	20	-5
PCI Q2020 2	100	100	50 R 50	-50
	75	75	70-100	0
	50	49	50	1
	25	24	20	-4
PCI Q2020 3	100	100	40 R 40	-60
	75	71	50	-21
	50	41	30	-11
	25	12	0-10	-2
PCI Q2020 4	100	100	CCV-FAIL 20 R	-80
	75	74	70-100	0
	50	48	50	2
	25	22	20	-2
PCI Q2020 5	100	100	CCV-FAIL 40 R	-60
	75	74	70-100	0
	50	48	50	2
	25	22	20	-2
BAL Q2020 1	100	100	70-100	0
	75	75	70-100	0
	50	50	50	0
	25	25	30	5
BAL Q2020 2	100	100	70-100	0
	75	75	70-100	0
	50	50	50	0
	25	25	30	5
BAL Q2020 3	100	100	70-100	0
	75	75	70-100	0
	50	50	50	0
	25	25	30	5

"R" indication denotes retest

Table 7
Results of QPS State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at -20C and Tested at 0C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI Q-2000 1	75	71	50	-21
	50	42	30	-12
	25	12	0-10	-2
PCI Q-2000 2	75	74	60	-14
	50	47	40	-7
	25	21	0-10	-11
PCI Q-2000 3	75	72	40	-32
	50	43	30	-13
	25	15	0-10	-5
PCI Q-2000 4	75	69	40	-29
	50	38	20	-18
	25	7	0-10R 0-01R	0
BAL Q-2000 1	75	76	60	-16
	50	53	40	-13
	25	29	30	1
BAL Q-2000 2	75	77	60	-17
	50	53	40	-13
	25	30	30	0
BAL Q-2000 3	75	74	40	-34
	50	47	30	-17
	25	21	20	-1

R indication denotes retest

Table 8
Results of QPS State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at -20C and Tested at 20C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI Q-2020 1	75	71	50	-21
	50	43	40	-3
	25	14	0-10	-4
PCI Q-2020 2	75	71	50	-21
	50	43	40	-3
	25	14	0-10	-4
PCI Q-2020 3	75	73	60	-13
	50	46	40	-6
	25	20	20	0
PCI Q-2020 4	75	72	60	-12
	50	43	20	-23
	25	15	0-10	-5
BAL Q-2020 1	75	72	70-100	0
	50	45	50	5
	25	17	20	3
BAL Q-2020 2	75	69	60	-9
	50	38	40	2
	25	7	0-10	0

Table 9
Results of QPS State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at 50C and Tested at 50C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI Q5050 1	75	75	70-100	0
	50	51	50	-1
	25	26	20	-6
PCI Q5050 2	75	76	70-100	0
	50	52	50	-2
	25	28	20	-8
PCI Q5050 3	75	76	70-100	0
	50	52	50	-2
	25	28	20	-8
PCI Q5050 4	75	76	70-100	0
	50	52	40	-12
	25	28	20	-8
PCI Q5050 5	75	75	70-100	0
	50	51	40	-11
	25	26	20	-6
BAL Q5050 1	75	75	70-100	0
	50	49	50	1
	25	24	20	-4
BAL Q5050 2	75	75	70-100	0
	50	51	50	-1
	25	26	30	4
BAL Q5050 3	75	75	60	-5
	50	50	50	0
	25	26	20	-6

Table 10
Results of RBB State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at 20C and Tested at 20C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI R2020 1	100	100	33 55	-67 -45
	75	74	>70	0
	50	48	57	9
	25	22	25	3
PCI R2020 2	100	100	46 52	-54 -48
	75	74	>70	0
	50	49	56	7
	25	23	27	4
PCI R2020 3	100	100	28 49	-72 -51
	75	74	>70	0
	50	49	61	12
	25	23	29	6
BAL R2020 1	100	100	>70	0
	75	75	>70	0
	50	49	51	2
	25	24	28	4
BAL R2020 2	100	100	>70	0
	75	75	>70	0
	50	51	54	3
	25	26	31	5

Table 11
Results of RBB State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at -20C and Tested at 0C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI R-2000 1	75	70	63	-7
	50	41	45	4
	25	11	19	8
PCI R-2000 2	75	71	44	-27
	50	42	39	-3
	25	14	15	1
PCI R-2000 3	75	71	41	-30
	50	42	36	-6
	25	14	14	0
BAL R-2000 1	75	70	41	-29
	50	41	30	-11
	25	11	23	12
BAL R-2000 2	75	71	47	-24
	50	42	34	-8
	25	13	26	13
BAL R-2000 3	75	71	37	-34
	50	42	27	-17
	25	13	20	7

Table 12
Results of RBB State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at -20C and Tested at 20C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI R-2020 1	75	70	62	-8
	50	41	43	2
	25	11	19	8
PCI R-2020 2	75	71	56	-14
	50	42	42	0
	25	14	20	6
BAL R-2020 1	75	70	60	-10
	50	41	41	0
	25	11	21	10
BAL R-2020 2	75	71	59	-12
	50	42	41	-1
	25	13	20	7

Table 13
Results of RBB State of Charge Meter Evaluation for BA-5800/U Batteries Discharged at 50C and Tested at 50C

Battery Identification	Target SOC	Achieved SOC	Predicted SOC	Prediction Error
PCI R5050 1	75	75	>70	0
	50	51	55	4
	25	26	27	1
PCI R5050 2	75	75	>70	0
	50	50	57	7
	25	25	24	-1
PCI R5050 3	75	75	>70	0
	50	51	60	9
	25	26	25	-1
BAL R5050 1	75	75	>70	0
	50	49	>70	20
	25	24	30	5
BAL R5050 2	75	75	>70	0
	50	50	69	19
	25	25	31	6
BAL R5050 3	75	75	>70	0
	50	51	>70	19
	25	26	34	8

3.0 HUMAN FACTORS ENGINEERING EVALUATION FOR STATE OF CHARGE METERS FOR BA-5800/U LITHIUM SULFUR DIOXIDE BATTERIES

A. During the Battery Tester test, Human Factors Engineering (HFE) data were collected in the form of soldiers' written comments on the Bashe Meter, free form comments for the Bashe Meter, a questionnaire for the QPS Meter, and through a soldier verbally stating his likes and dislikes on the QPS Meter. Unfortunately, there is not a lot of HFE data (especially on the QPS meter), and the questionnaire was not used for both meters.

1. Results on the Bashe meter are the following:

a. Reported Advantages:

(1) This tester offers a wider range of battery manufactures that can be safely tested.

b. Reported areas that could use improvement:

(1) Three out of five soldiers stated that the connector that attaches to the tester (from the battery) has disconnected during testing.

(2) One out of five soldiers stated that the cable that runs between the tester and the battery should be more flexible. A related comment was from another of the five soldiers, who stated that the cable that runs between the tester and the battery is susceptible to becoming broken, i.e., the cable's durability is in question.

(3) One out of five soldiers stated that it would be an improvement to the tester if it had an audible alarm. This feature would likely increase the efficiency of testing large quantities of batteries.

(4) One out of five soldiers stated that when testing the same battery on two different meters the soldier received two different readings, one for 70% charge and the other for below 50%.

(5) One out of five soldiers stated that the tester should state the actual percent of battery state of charge vs. above or below a percentage (e.g., 90% vs. >70%) of battery state of charge.

(6) Two out of five soldiers stated that they would like the meter to complete a battery test faster.

(7) The size of the Bashe Meter does not permit the unit to fit into Battle Dress Uniform pockets.

c. One comment on the QPS Meter was that it should be made pocket size for field use, this would also apply to the Bashe Meter as an area for improvement.

2. The results on the QPS meter are lacking; the results are from one soldier and are the following:

a. Reported Advantages: This tester offers a screwdown connector to prevent the cable from becoming disconnected during a test.

b. Reported areas that could use improvement:

(1) Make this a pocket size unit for use in the field.

(2) Would like the tester to perform a test faster.

c. Even though it was not formally stated in the test data (as it was for the Bashe Meter), it is an advantage to the QPS Meter that it can safely test the same battery manufacturers as the Bashe Meter.

d. Since the QPS Meter takes approximately the same amount of time to test a battery as the Bashe Meter, does not show battery life percentages above 70%, and does not have an audible alarm, some of the same soldiers' comments that were stated on the Bashe Meter can be applied to the QPS Meter as areas for improvement; these are the following:

(1) The Meter should complete a battery test faster.

(2) The tester should state the actual percent of battery state of charge vs. above or below a percentage (e.g., 90% vs. >70%) of battery state of charge.

(3) It would be an improvement to the tester if it had an audible alarm. This feature would likely increase the efficiency of testing large quantities of batteries.

B. In summary, both meters have similar HFE shortfalls. However, the QPS has the advantage of providing a screwdown connector to prevent the cable from becoming disconnected during battery testing.

APPENDIX A - BATTERY TEST DATA AND SUMMARY DATA

BA-5800 BALLARD

	New				Used						
Datasheet	> 70	=70	< 70	Range (Dead)	Reissued as New > 70	Reissued as New =70	Reissued Training 38-69	Turned In <=37	Turned In Range (Dead)	Turned In Open	Turned In No Rdg
1											
2			11								
3			15								
4			14								
5			1		2	8	3		5		
6		5	1				2	1			
7		6	6								
8	2	9	15				1	3			
9											
10											
11											
12		3	8			2	6	2	1	2	
13											
14	1	5		1							
15											
16											
17											
18					2	13	1		2		
19											
20	2	14		1			12		1		
TOTAL	5	42	71	2	4	23	25	6	9	2	0

Total New = 120

Total Used = 69

Total New + Used = 189

BA-5800 PCI

	New				Used						
Datasheet	> 70	=70	< 70	Range (Dead)	Reissued as New > 70	Reissued as New =70	Reissued Training 38-69	Turned In <=37	Turned In Range (Dead)	Turned In Open	Turned In No Rdg
1						14			16		
2		14				3		2			
3		1	8	1							
4						3			13		
5							9	2			
6		5	1								
7						9		1	8		
8											
9	1	7	21								
10											
11											
12			4								
13											
14	5	13	1	4							
15											
16											
17					3	12	1		1		
18						5	1		1		
19											
20											
TOTAL	6	40	35	5	3	46	11	5	39	0	0

Total New = 86 **Total Used = 104** **Total New + Used = 190**

5800 **BALLARD** **NEW** **≥70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	72	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	79	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	72	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	75	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	72	1ST
								TOTAL	**5**	

5800 **BALLARD** **NEW** **=70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	70	1ST

11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	70	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	70	1ST
								TOTAL	**42**	

5800 **BALLARD** **NEW** **≤70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	53	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	51	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	51	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	52	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	51	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	11	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	50	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	58	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	52	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	50	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	BALLARD	NEW	49	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	48	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	48	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	49	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	48	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	49	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	55	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	49	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	51	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	48	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	51	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	50	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	18	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	49	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	59	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	BALLARD	NEW	48	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	61	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	59	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	59	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	57	1ST

11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	60	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	60	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	62	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	63	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	60	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	62	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	63	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	66	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	NEW	62	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	60	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	67	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	68	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	67	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	68	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	69	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	69	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	67	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	67	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	67	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	47	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	69	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	69	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	68	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	68	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	69	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	66	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	NEW	64	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	66	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	62	1ST

11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	54	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	24	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	53	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	65	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	NEW	58	1ST
								TOTAL	**71**	

5800 **BALLARD** **NEW** **RANGE**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	NEW	RANGE	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	NEW	RANGE	1ST
								TOTAL	**2**	

5800 **BALLARD** **USED** **≥70**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	72	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	72	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	71	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	71	1ST
								TOTAL	**4**	

5800 **BALLARD** **USED** **=70**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	70	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	70	1ST
								TOTAL	23	

5800 **BALLARD** **USED** **>=38** **<=69**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	65	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	65	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	65	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	USED	61	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	USED	56	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	USED	49	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	68	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	61	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	62	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	58	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	68	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	68	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	69	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	48	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	50	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	50	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	52	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	53	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	50	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	50	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	55	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	50	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	62	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	55	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	43	1ST
								TOTAL	**25**	

5800 **BALLARD** **USED** **<=37**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	BALLARD	USED	18	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	USED	0	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	USED	27	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	BALLARD	USED	0	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	36	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	30	1ST
								TOTAL	**6**	

5800 **BALLARD** **USED** **RANGE**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	RANGE	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	RANGE	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	RANGE	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	RANGE	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	BALLARD	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	BALLARD	USED	RANGE	1ST
1/15/96	COMMO SHOP	10	TAYLOR	1453 U	RBB	5800	BALLARD	USED	RANGE	1ST
								TOTAL	**9**	

5800 **BALLARD** **USED** **OPEN**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	OPEN	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	BALLARD	USED	OPEN	1ST
								TOTAL	**2**	

5800 **PCI** **NEW** **>70**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	71	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	72	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	75	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	75	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	72	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	71	1ST
								TOTAL	**6**	

5800 **PCI** **NEW** **=70**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST

11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	PCI	NEW	70	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	70	1ST
								TOTAL	**40**	

5800 PCI NEW ≤70

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	62	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	43	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	43	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	59	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	33	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	36	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	44	1ST
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	53	1ST
11/22/95	COMMO SHOP	21	McKENZIE	1451 U	RBB	5800	PCI	NEW	68	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	69	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	68	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	51	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	60	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	67	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	54	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	47	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	60	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	60	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	61	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	67	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	48	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	63	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	53	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	66	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	64	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	58	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	69	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	63	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	61	1ST
11/27/95	COMMO SHOP	21	JACKSON	1452 U	RBB	5800	PCI	NEW	64	1ST

11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	PCI	NEW	27	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	PCI	NEW	48	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	PCI	NEW	47	1ST
11/22/95	COMMO SHOP	20	ZUMANT	1454	RBB	5800	PCI	NEW	46	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	68	1ST
								TOTAL	**35**	

5800 **PCI** **NEW** **RANGE**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21	G. BOSS	1453 U	RBB	5800	PCI	NEW	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	NEW	RANGE	1ST
								TOTAL	**5**	

5800 **PCI** **USED** **≥70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	72	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	72	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	71	1ST
								TOTAL	**3**	

5800 **PCI** **USED** **=70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST

11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	70	1ST
								TOTAL	**46**	

5800 **PCI** **USED** **>=38** **<=69**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	42	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	50	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	50	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	51	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	50	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	50	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	42	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	55	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	40	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	65	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	69	1ST
								TOTAL	11	

5800 **PCI** **USED** **<=37**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	USED	0	1ST
11/22/95	COMMO SHOP	21		1453 U	RBB	5800	PCI	USED	0	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	30	1ST
11/22/95	COMMO SHOP	18	McKENZIE	1451 U	RBB	5800	PCI	USED	30	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	0	1ST
								TOTAL	5	

5800 **PCI** **USED** **RANGE**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	21	S. TAYLOR	1453 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST

11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	19	McKENZIE	1451 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
11/22/95	COMMO SHOP	20	JACKSON	1452 U	RBB	5800	PCI	USED	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	RANGE	1ST
1/15/96	COMMO SHOP	10	SMITH	1453 U	RBB	5800	PCI	USED	RANGE	1ST
								TOTAL	**39**	

BA-5800 Ballard

Datasheet	New > 70	New =70	New < 70	New Range (Dead)	Used (All these were on the 2nd test) Reissued as New > 70	Reissued as New =70	Reissued Training 38-69	Turned In <=37	Turned In Range (Dead)	Turned In Open	Turned In No Rdg
1	4	25	1								
2	2	26	2								
3	2	20	1								
4								30			
5							4	26			
6							1	29			
7											
8											
9											
10											
11											
12											
13											
TOTAL	8	71	4	0	0	0	5	85	0	0	0

Total New = 83 **Total Used = 90** **Total New + Used = 173**

5800 **BALLARD** **NEW** **>70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	72	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	72	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	72	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	75	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	72	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	81	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	82	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	72	1ST
								TOTAL	**8**	

5800 **BALLARD** **NEW** **70**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST

7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST

7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	70	1ST
								TOTAL	71	

5800 **BALLARD** **NEW** **<70**

DATE	TEST LOC	TEMP ^{0}C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	69	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	62	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	69	1ST
7/8/96	COMMO SHOP	65	SSG SMITH	1451 U	RBB	5800	BALLARD	NEW	69	1ST
								TOTAL	4	

5800 **BALLARD** **USED** **>70**

None

5800 **BALLARD** **USED** **=70**

None

5800 **BALLARD** **USED** **>=38** **<=69**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	39	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	42	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	50	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	39	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	62	2ND
								TOTAL	**5**	

5800 **BALLARD** **USED** **<=37**

DATE	TEST LOC	TEMP °C	TECH	SOC MTR #	MTR MFR	BATTERY TYPE	BATTERY MFR	NEW/USED	SOC%	TEST NUM
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	26	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND

6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	32	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	32	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	32	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND

6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	29	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
6/28/96	COMMO SHOP	67	SGT TAYLOR	1454 U	RBB	5800	BALLARD	USED	0	2ND
								TOTAL	**85**	

APPENDIX B - ECONOMIC ANALYSIS CALCULATIONS, COST DATA INPUTS, SOURCES

PLGR SOC METER EA CALCULATIONS

	STATUS QUO		ALTERNATIVE A			
O&S COSTS			INVESTMENT COSTS		O & S COSTS	
FISC YR	ITEM	COST ($)	ITEM	COST ($)	ITEM	COST ($)
Sum 1996		**0**		**0**		**0**
1997	Batt Demd x Unit Cost 213,267 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	3,798,285 53,317	No. x meter cost 228 @ $1200	273,600	1/2 Batt Demd x UC x .6 106,634 @ Unit Cost $17.81 1/2 Batt Demd x UC 106,634 Disposal Costs .25/lb x 1lb x .6 .25/lb x 1lb	1,139,486 1,899,143 15,995 26,658
Sum 1997		**3,851,602**		**273,600**		**3,081,282**
1998	Batt Demd x Unit Cost 229,262 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,083,156 57,316			1/2 Batt Demd x UC x .6 114,631 @ Unit Cost $17.81 1/2 Batt Demd x UC 114,631 Disposal Costs .25/lb x 1lb x .6 .25/lb x 1lb	1,224,947 2,041,578 17,195 28,658
Sum 1998		**4,140,472**		**0**		**3,312,377**
1999	Batt Demd x Unit Cost 246,457 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,389,399 61,614			1/2 Batt Demd x UC x .6 123,229 @ Unit Cost $17.81 1/2 Batt Demd x UC 123,229 Disposal Costs .25/lb x 1lb x .6 .25/lb x 1lb	1,316,820 2,194,700 18,484 30,807
Sum 1999		**4,451,013**		**0**		**3,560,811**
2000	Batt Demd x Unit Cost 246,457 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,389,399 61,614		0	1/2 Batt Demd x UC x .6 123,229 @ Unit Cost $17.81 1/2 Batt Demd x UC 123,229 Disposal Costs .25/lb x 1lb x .6 .25/lb x 1lb	1,316,820 2,194,700 18,484 30,807
Sum 2000		**4,451,013**				**3,560,811**
2001	Batt Demd x Unit Cost 246,457 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,389,399 61,614			1/2 Batt Demd x UC x .6 123,229 @ Unit Cost $17.81 1/2 Batt Demd x UC 123,229 Disposal Costs .25/lb x 1lb x .6 .25/lb x 1lb	1,316,820 2,194,700 18,484 30,807
Sum 2001		**4,451,013**		**0**		**3,560,811**
SUM FY		**21,345,114.**		**273,600**		**17,076,091**

SOC METER ALTERNATIVE COST AND BENEFITS DISPLAY ($K)

Evaluation Period	Constant Dollars (Base Year FY96): Operation Cost: Status Quo	SOC Alternative	Benefits (Differential Costs)	PV Factor	Discounted Dollars (Present Value): Benefits (Differential Costs)	Inf Factor	Current Dollars (Inflated): Benefits (Differential Costs)
(1)	(2)	(3)	(4) = (2) - (3)		(5) = (4) x Disc. Fac.		(6) = (4) x Infl. Fac.
FY 96			0	0	0	0.995	0
FY 97	3,851,602	3,081,282	770,320	0.9868	760,152	1.0164	782,954
FY 98	4,140,472	3,312,377	828,094	0.9608	795,633	1.0392	860,556
FY 99	4,451,013	3,560,811	890,203	0.9356	832,874	1.0625	945,840
FY 00	4,451,013	3,560,811	890,203	0.911	810,975	1.0859	966,671
FY 01	4,451,013	3,560,811	890,203	0.887	789,610	1.1098	987,947
FY 02			0	0.8637		1.1342	0
Residual Value							
Total	21,345,114	17,076,091	4,269,023		3,989,243 (7)		4,543,968 (10)
		Investment Cost			Investment Cost		Investment Cost
		273,600			269,988 (8)		278,087 (11)
		Project Total Cost			Net Present Value		Net Benefits
		17,349,691			3,719,255 (9)		4,265,881

BIR= 14.78 SIR= 14.78

Cost Data Inputs and Sources:

	Source
BA-5800/U Battery Fielding Data	J. Monahan, AMC Battery Group, X24341
PLGR Fielding Data	M. Wilkin, PM GPS, X26131
BA-5800/U Battery, AMDF FY 97 Price = $17.81	S. Moran, AMC Battery Group, X24949
RBB DM 301 SOC Meter cost: $4000 per unit in quantity of 6	M. Wilkin, PM GPS, X26131
QPS SCO Meter Cost: $4000 per unit in quantity of 6	M. Wilkin, PM GPS, X26131
Meter Cost: $1200 per unit in quantity of 92	R. Scarinzi, LRC Battery Group, X21925
Battery Disposal Cost: 0.25 cents/pound	C. Rutkowski, AMC Battery Group, X28941

SIR, based on 10 years form start of savings (Present Value $) =
PV Benefits FY 97 through FY 06 / Investment, =
3,989,243 / 269,988 = 14.78

BIR, based on 20 year life cycle, = Life Cycle PV Benefits / Investment Cost
3,989,243 / 269,988 = 14.78

27 February 1996 DA inflation tables were utilized for the analysis. For inflation purposes, Operations and Maintenance Army (OMA) tables, base year 1997 composite were utilized. The 26 February 1996 DA memorandum on discount rates in use in economic analyses was in compliance. The 2.8% mid year factors were utilized.

Alternative A	**PAYBACK CALCS**	Savings =	Investment
X =	Alt A Invest = 2,935K	Current $	
Y =	Svgs Yr 1 = 673K		
Z = .1 Svgs Yr 7	Svgs Yr 2 = 3,457K; =346K per .1 Yr		
Pybk = 1+	(X-Y)/Z = 1 + .654 = 1.6 Years		

INFLATION
Base Year = 1997

			Composite	FY
PRESENT WORTH FACTORS		P	0.995	1996
0 =<P<6	0.9868	1	1.0164	1997
Rate = 0.028	0.9608	2	1.0392	1998
	0.9356	3	1.0625	1999
	0.911	4	1.0859	2000
	0.887	5	1.1098	2001
	0.8637	6		

APPENDIX C - SENSITIVITY ANALYSIS CALCULATIONS

SENSITIVITY COST CALCULATIONS

	STATUS QUO		ALTERNATIVE A			
O&S COSTS			INVESTMENT COSTS		O & S COSTS	
FISC YR	ITEM	COST ($)	ITEM	COST ($)	ITEM	COST ($)
1996						
Sum 1996		**0**		**0**		**0**
1997	Batt Demd x Unit Cost 213,267 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	3,798,285 53,317	No. x meter cost 228 @ $1200	273,600	1/2 Batt Demd x UC x .8 106,634 @ Unit Cost $17.81 1/2 Batt Demd x UC 106,634 Disposal Costs .25/lb x 1lb x .8 .25/lb x 1lb	1,519,314 1,899,143 21,327 26,658
Sum 1997		**3,851,602**		**273,600**		**3,466,442**
1998	Batt Demd x Unit Cost 229,262 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,083,156 57,316			1/2 Batt Demd x UC x .8 114,631 @ Unit Cost $17.81 1/2 Batt Demd x UC 114,631 Disposal Costs .25/lb x 1lb x .8 .25/lb x 1lb	1,633,262 2,041,578 22,926 28,658
Sum 1998		**4,140,472**		**0**		**3,726,425**
1999	Batt Demd x Unit Cost 246,457 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,389,399 61,614			1/2 Batt Demd x UC x .8 123,229 @ Unit Cost $17.81 1/2 Batt Demd x UC 123,229 Disposal Costs .25/lb x 1lb x .8 .25/lb x 1lb	1,755,760 2,194,700 24,646 30,807
Sum 1999		**4,451,013**		**0**		**4,005,912**
2000	Batt Demd x Unit Cost 246,457 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,389,399 61,614			1/2 Batt Demd x UC x .8 123,229 @ Unit Cost $17.81 1/2 Batt Demd x UC 123,229 Disposal Costs .25/lb x 1lb x .8 .25/lb x 1lb	1,755,760 2,194,700 24,646 30,807
Sum 2000		**4,451,013**				**4,005,912**
2001	Batt Demd x Unit Cost 246,457 @ Unit Cost $17.81 Disposal Costs .25/lb x 1lb	4,389,399 61,614			1/2 Batt Demd x UC x .8 123,229 @ Unit Cost $17.81 1/2 Batt Demd x UC 123,229 Disposal Costs .25/lb x 1lb x .8 .25/lb x 1lb	1,755,760 2,194,700 24,646 30,807
Sum 2001		**4,451,013**				**4,005,912**
SUM FY		**21,345,114.**		**273,600**		**19,210,603**

COST AND BENEFITS DISPLAY ($K)

	Constant Dollars (Base Year FY96)			PV Factor	Discounted Dollars (Present Value)	Inf Factor	Current Dollars (Inflated)
Evaluation	Operation Cost		Benefits		Benefits		Benefits
Period	Status Quo	Alternative A	(Differential Costs)		(Differential Costs)		(Differential Costs)
(1)	(2)	(3)	(4) = (2) - (3)		(5) = (4) x Disc. Fac.		(6) = (4) x Infl. Fac.
FY 96	.	0	0	0	0	0.995	0
FY 97	3,851,602	3,466,442	385,160	0.9868	380,076	1.0164	391,477
FY 98	4,140,472	3,726,425	414,047	0.9608	397,817	1.0392	430,278
FY 99	4,451,013	4,005,912	445,101	0.9356	416,437	1.0625	472,920
FY 00	4,451,013	4,005,912	445,101	0.911	405,487	1.0859	483,336
FY 01	4,451,013	4,005,912	445,101	0.887	394,805	1.1098	493,973
FY 02				0.8637	0	1.1342	0
Residual Value							
Total	21,345,114	19,210,603	2,134,511		1,994,622 (7)		2,271,984 (10)
		Investment Cost			Investment Cost		Investment Cost
		273,600			269,852 (8)		278,087 (11)
		Project Total Cost			Net Present Value		Net Benefits
		19,484,203			1,724,770 (9)		1,993,897

BIR= 7.39 SIR= 7.39

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